THE TRAVERSE PLANNING PROCESS FOR THE DRATS 2010 ANALOG FIELD SIMULATIONS.

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Introduction: Traverse planning concentrates on optimizing the science return within the overall objectives of planetary surface missions or their analog field simulations. Such simulations were conducted in the San Francisco Volcanic Field, northern Arizona, from Aug. 26 to Sept 17, 2010 and involved some 200 individuals in the field, with some 40 geoscientists composing the science team. The purpose of these Desert Research and Technology Studies (DRATS) is to exercise and evaluate developmental hardware, software and operational concepts in a mission- like, fully-integrated, setting under the direction of an onsite Mobile Mission Control Center(MMCC).

DRATS 2010 focused on the simultaneous operation of 2 rovers, a historic first. Each vehicle was manned by an astronaut-commander and an experienced field geologist. Having 2 rovers and crews in the field mandated substantially more complex science and mission control operations compared to the single rover DRATS tests of 2008 and 2009, or the Apollo lunar missions. For instance, the science support function was distributed over 2 "back rooms", one for each rover, with both "tactical" teams operating independently and simultaneously during the actual traverses. Synthesis and integration of the daily findings and forward planning for the next day(s) was accomplished overnight by yet another "strategic" science team [1].

Major Constraints: Within the overall objective of operating 2 rovers simultaneously on 12 traverse days, DRATS 2010 specifically tested contrasting modes of communication and rover operations. Communication modes included 6 days of "continuous communication" (CC) where the crews were in continuous contact with MMCC and the tactical science teams, and 6 days of absolutely no communications except once in the morning and once in the evening (2X for short). The 2X mode emulates – in simplified fashion – a single communication satellite in a highly elliptical orbit. Within the CC days, there were 3 days each where a) both rovers operated in complementary proximity (termed "Lead and Follow"; L&F) or b) where each rover explored spatially separate geologic features in rather independent fashion (termed "Divide and Conquer"; D&C). All of the 2X days were of the L&F type. Obviously, traverse planning had to account for these widely different communication modes and rover operations in addition to an assortment of other constraints (e.g. the transmission range of specific communication assets, or average speed and power budget of each rover). It also needed to accommodate all safety concerns of crew and vehicles, the latter manifested in numerous procedures and "mission rules". As a consequence, traverse planning becomes a very complex endeavor that must continuously balance the science objectives with a wide diversity of engineering and other mission interests. It is also important to note that existing literature and other forms of geologic ground truth are disallowed throughout the traverse planning process, as well as during the execution of the field simulations, and potential post-mission analyses.

Early Planning: The planning process began with detailed photo-geologic analysis and mapping of GeoEYE satellite images (0.50 m/pixel resolution) and derivative topographic products (hillshade; slope etc; at 1.5m /pixel) of the test area [2] following the guidelines for contemporary planetary mapping methods and products of [3]. These efforts provided a contextual framework to delineate major objectives regarding the formation and evolution of recognizable, mapped geologic units. Also a series of locations was identified where many of the outstanding questions could possibly be addressed, if not solved, on the ground. Major and minor science objectives were then ranked by priority, and locations where these objectives could be addressed best were identified and ranked as well.

Having reached some fairly mature understanding of the science objectives, a Traverse Workshop was held in early March 2010 with all science, engineering, operations and human factor interests present. This workshop not only formalized the science objectives, but it also established most first order operational constraints and a series of mission rules, all resulting from many meetings and trade-offs prior to the workshop. This meeting also established that the ground-based communication architecture for audio and imagery provided the most severe constraints on where the rovers could go, because the rovers and MMCC had to be linked through a series of line-of-sight repeater stations over as much as 25 km distance. This demanded that the repeater stations as well as the rover-based communication assets had to be sited on local promontories. Using the digital elevation map, the area within line-of-sight of the rover-based assets was determined; it was within this area that all EVA activities had to take place during the CC days. Obviously, all night camps had to be on local promontories as well, as all operational modes mandated full communications at the end and beginning of a daily traverse and to facilitate extensive data downloads overnight. The above workshop finished with a well defined, nearly contiguous, series of "communication foot prints" within which all traverse activities had to be staged; by design, these foot prints contained all high priority science sites and many others suitable for productive field work.

Within these constraints, a series of 24 preliminary traverses was designed (12 days; 2 rovers each). This activity drew heavily on the topographic data sets that helped identify areas too rough or too steep to be traversed by the rovers and support convoy. Subsequently, these preliminary traverses were surveyed in the field (in late April 2010) to address trafficability and logistics issues that could not be resolved from aerial imagery, such as fences and available gates, road conditions (for support vehicles), specific locations for communication assets etc. This field reconnaissance resulted in significant changes to 6 preliminary traverses, eliminating a single day altogether due to rough terrain. Though obviously unrealistic in a real planetary mission context, field-based verification of specific routes and sites is indispensible in the context of analog exercises to assure that all high priority test objectives are realistic and compatible with the detailed field conditions.

Final Planning: Four months prior to the actual analog mission, the detailed traverse planning began in earnest and included, for the first time, an attempt to define realistic time lines. Many of the non-science operations were sufficiently mature by that time that they allowed quantitative inputs into the daily timeline. Foremost, total traverse duration was defined to be 8:35 hrs for CC days and 7:55 hrs for 2X days; this somewhat shorter traverse time is caused by the need for longer daily pre-and de-briefs of the crew for the 2X mode. Times were also available for rover egress and ingress, the operation and deployment of communication gear, meal times, and trash operations. The remaining "discretionary" time was then split between driving (at average speed of 5 km/hr) and EVA/boots on the ground geologic field work. The typical traverse day consists of 3-4 stations (4-5 hours with 2-3 hours of "boots on the ground"), approximately 2 hours/10 km of driving, a 1 hour break for meals and Human Factors needs, and close to 1 hour of antenna operations and trash removal. Approximately 3 months prior to the field test, all traverse plans were available as kml files accompanied by time lines at a resolution of 5 min. DRATS 2010 called for 12 individual traverses over some 130 km distance per rover, which included 40 individual EVA stations for detailed field observations and the acquisition of representative rock and soil samples. Fine-tuning of the time line, with ever increasing fidelity of operational constraints based on dry runs at JSC, continued into early August 2010.

The final products for each of the 12 mission days and for each rover were 1) a Google Earth-based KML map depicting specific routes, navigation points, and station locations and 2) two daily spreadsheets that defined, at different levels of detail, the time-line, navigation data, and the objectives of specific operational or scientific tasks to be conducted while driving or while EVA. These nominal documents were updated and modified daily by the strategic science team and others on an as-needed-basis during the actual field tests; they were uploaded to the rovers between 6:00 and 7:00 every morning, together with other briefing materials of significance for the upcoming traverse.

Conclusions: The most critical part of the traverse planning process is the capture of science objectives and their priorities at the level of the overall mission, of a daily traverse, and individual stations. This has to occur relatively early in the planning process, because these objectives and priorities underpin all traverse planning and are the drivers for specific traverse routes and EVA activities. Another critical aspect of traverse planning relates to the genuine comprehension and detailed understanding of numerous operational constraints, an educational process for all involved. Without the generous collaboration and palpable team spirit of many, the DRATS 2010 traverse planning would have not been possible.

To the outsider, some of this detailed planning may appear overly scripted, a critique occasionally leveled at the Apollo surface operations. However, this detailed planning is necessary to account for all operational constraints and to maximize the efficiency and resources of a rather large, highly diverse, and costly ground support system.

References: [1] Eppler, D. *et al.* 2010 (this volume); [2] Skinner, J. A. and Fortezzo, C. M., 2010 (this volume). [3] Tanaka, K. L. *et al.*, 2009, NASA/CP-2010-216680.